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Solar irrigation market analysis in Mozambique

Green People´s Energy

Imprint

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1. INTRODUCTION

1.1 BACKGROUND

Solar powered irrigation systems

Over the last decade, the price of solar panels has decreased drastically, bringing solar PV technologies within reach for viable industrial, domestic and agricultural applications worldwide. Solar Powered Irrigation Systems (SPIS) in particular are increasingly valued and stimulated by governments and donors thanks to its crosscutting merits impacting on food security, water access, energy and climate. Over the past five years, a number of companies have developed and launched solar pumps for smallholder farmers. These companies are attractive to a large crowd of investors, as shown by the recent investment rounds of Futurepump Ltd, with 1 million USD raised within months[1], and Sunculture, with $14 million USD raised in equity and another $11 million USD in debt[2].

Stimulating solar irrigation is an effective climate change mitigation strategy that can potentially reduce the CO2 emissions per energy unit of water pumping (CO2-eq/kWh) by 97 to 98 percent as compared with diesel pumps, following a life cycle assessment by GIZ (FAO, 2018). The opportunity offered by solar irrigation for sustainable development, reduction of emissions and climate resilience makes it a preferred contender for climate financing (FAO, 2018)[3]. Frontrunners of SPIS promotion are Bangladesh, India and Morocco where the governments have ambitious targets and subsidy programs in place to support the uptake of SPIS and reduce dependency on fossil fuels. Since recently, countries in Sub Saharan Africa are following this trend, generally backed by international grants of favourable loans aimed at the promotion of sustainable energy.

Solar irrigation can provide a clean and potentially cost-effective solution to increase agricultural production. Access to water for irrigation is key to many small-scale farmers in order to sustain their livelihoods and increase food security (FAO, 2015b[4]). SPIS provides opportunities for small-scale private farmers to reduce out-of-pocket production costs related to fuel powered pumps. Submersible solar pumps also enable irrigation development in areas with slightly deeper groundwater that cannot be accessed by fuel-powered suction pumps.

In some countries with supportive government policies, the demand for solar pumps is growing rapidly. In India the demand for solar pumps is rigorously increasing thanks to consistent government subsidies. As an example: up to 90% of the price of small solar pumps in Bihar state is subsidized (IISD, 2019[5]). Yet, the physical, socio-economic, commercial and institutional landscape are a large determinant for the growth and sustainability of SPIS development. This study, commissioned by GIZ Mozambique, shows the results of a country-specific assessment of the current state and barriers of solar-powered irrigation development in Mozambique.

[1] https://www.crowdcube.com/companies/futurepump/pitches/bqKvzb
[2] https://www.linkedin.com/pulse/sunculture-annual-letter-2020-samir-ibrahimc/?trackingId=4rFS%2BDbmzQeUMRUqzhIcyg%3D%3D
[3] http://www.fao.org/3/i9047en/I9047EN.pdf
[4] https://docplayer.net/21322556-International-workshop-prospects-for-solar-powered-irrigation-systems-spis-in-developing-countries.html
[5] https://www.iisd.org/sites/default/files/publications/solar-irrigation-across-wef-nexus-india.pdf

Green People's Energy Mozambique

GIZ Mozambique holds a broad portfolio of global initiatives that promote the uptake of renewable energy and aims at increasing energy access and improving the living conditions of the population through the productive use of energy. Amongst those initiatives are the ongoing Energising Development (EnDev), the Green People's Energy for Africa Programme (GBE) and GET Invest.

The Green People's Energy for Africa Programme (GBE) in Mozambique is part of a global programme implemented from 2018 to 2022. The GBE Mozambique programme is implemented through the EnDev Mozambique project. In Mozambique GBE focusses on promoting the productive use of decentralised renewable energies and the electrification of social institutions. The aim above all is economic development by increasing local value chains and employment. By advising local businesses and promoting local training centres, local people are empowered to take development into their own hands. Small and medium-sized enterprises are supported in the acquisition of electrical appliances and equipment as well as in improving their business models and optimizing their profitability.

In southern Mozambique harvest failure due to increasing droughts is common. Rain-fed food production is limited to one crop a year and poses high risks for local food security. Irrigation could potentially reduce risks and increase income for smallholder farmers as it enables off-season production and supplementing water when rainfall is insufficient. In this context, this study was launched to look at the feasibility of introducing individual solar-powered irrigation packages at small scale enterprise level in Mozambique.

1.2 SCOPE AND OBJECTIVE

The objective of the study is to formulate recommendations for the promotion of solar powered irrigation systems (SPIS) in Mozambique by conducting an analysis of the actual off-grid solar irrigation technologies available and its promotion for small scale enterprise level farmers (<2ha) in Mozambique. The analysis includes:

(i) Analysis of the current supply of small-scale solar powered irrigation technologies in Mozambique;

(ii) Reveal gaps, challenges and shortcomings for a sound development of the solar irrigation market for supply and demand side;

(iii) Provision of concrete Inputs and Recommendations in light of the specific GBE requirements on further development of activities and concepts.

1.3 METHODOLOGY

The research methodology is comprised of the following data collection methods:

1. **Stakeholder mapping** of suppliers, government institutions and NGOs involved in SPIS. The mapping was realized through online desk research, as well as through contacting manufacturers and distributors of known solar pump and irrigation brands.

2. **Online surveys** to collect data on the activities, products, services, challenges and growth strategies related to solar powered irrigation. Two surveys were developed to this end, one for the private sector and one for supporting organizations including NGOs and government institutions. Since the number of stakeholders involved in solar irrigation in Mozambique is still very small, the surveys were designed in a way to collect maximum input from a relatively small number of respondents. The following table shows the number

of surveys sent and the number of responses. The complete list and contacts of the private sector stakeholders can be found in Annex A.

Table 1 Overview of respondents per target group

	Private sector	NGOs	Government	Total
Number of surveys sent	25	19	8	52
Number of respondents	10	9	2	21
Respondent rate	40%	47%	25%	40%

For the private sector, the biggest solar pump suppliers and brands are all represented amongst the ten respondents. The remaining 15 contacts were either small retailers (6), general hardware providers (3), or somehow connected to the companies that already answered (6). As for the NGOs, surveys were only sent to organizations with some link to solar irrigation initiatives. Most organizations that have implemented projects with a significant solar irrigation component have replied. The two exceptions include an organization whose consortium partner had already replied (ADPP); as well as one project that has already closed (IFAD/PROSUL). The remaining non respondents were from NGOs with only a small solar irrigation component (8). As for the government, the main government stakeholder has replied, i.e. the Director-General of the national irrigation institute INIR. The remaining 7 surveys were sent to provincial government agencies responsible for the distribution of solar pumps (DPASA), yet only one reply was received at this level.

3. **Key expert interviews** were held after analysing the surveys, in order to validate the findings and discuss support strategies with the directors of the two largest solar pump suppliers in Mozambique. Attempts to also interview a key expert from the government were not successful.

2. SUPPLY OF SOLAR IRRIGATION TECHNOLOGIES

2.1 PRIVATE SECTOR INVENTORY

Manufacturers and available brands

The following table shows an overview of the available solar pump brands in Mozambique in January 2021. The pumps available on a distributor basis are featured by an annual sales volume of at least 100 pumps, for three years in a row. Retail volumes range from 2 to 25 pumps sold per year. Five manufacturers have confirmed that their pumps are not on the market in Mozambique yet. Two others companies, Sunculture and Dayliff are interested to enter in the future.

Table 2 Availability of solar pump brands in Mozambique

Available brands	Brands not available in Mozambique	Brands of which the presence is unknown
Lorentz – Retail	Ningbo	Difful
Grundfos – Distributor	Sunculture (but interested)	Xinya
Solartech - Distributor	Dayliff (but interested)	Mono

Futurepump –Distributor	Pumpmakers	Ennos Sunlight
Taifu – Retail	Spowdi	
Cedar Solar – Retail		
Feili – Retail		
Samking - Retail		
Shakti - Retail		
Jain - Retail		

As for irrigation equipment, at least four brands of drip systems are available in Mozambique: Shakti, Agriplas, Drip Tech India, and Netafim, as well as one brand of spray tubes: San Fu.

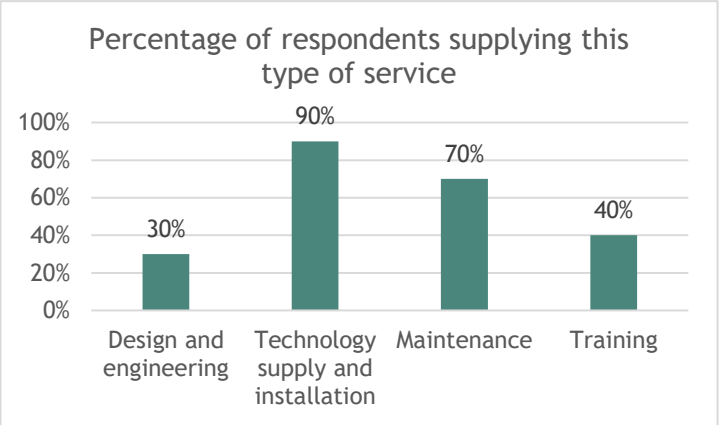
Solar irrigation suppliers in Mozambique

The distribution strategy varies amongst different manufacturers, some choosing for one exclusive national distributor per country, while others sell pumps to any company that is interested to sell their brand. Grundfos makes use of their authorized distribution partner and authorized service partner (Blue Zone), while Lorentz uses their standard distribution classification: in Mozambique they have one Distribution Partner (DP) and one Sales and Service Partner (SSP)[6]. Most solar pump suppliers in Mozambique sell at least two different brands, except for ProCampo that only sells Cedar Solar. There are also solar pump brands that have been introduced during projects, but that are not available for sales within Mozambique: Vida and Pumpmakers.

The following data are based on the results of the online survey responses from 10 solar pump and irrigation system suppliers in Mozambique. Amongst these respondents, most classify themselves as a national distributor (40%). As for the type of service provided, 90% of the respondents supply and install technologies. Design and engineering of the systems is only done by 30% of the respondents.

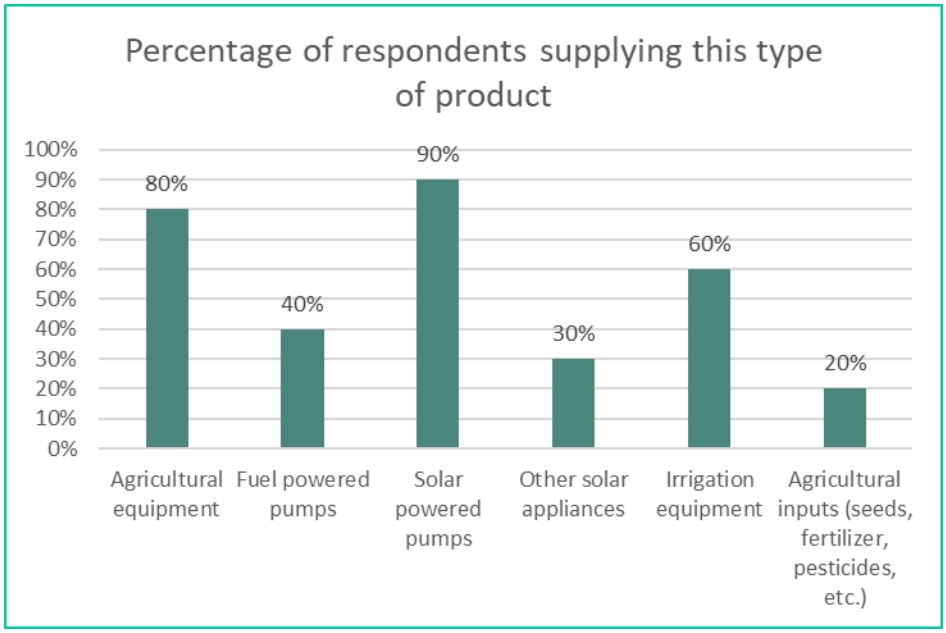
Table 3 Private sector respondents

Category of the private sector respondents		
Manufacturer	0	0%
National distributor	4	40%
Retailer	1	10%
Agent	2	20%
Engineering services	2	20%
Agrodealer	1	10%
Total	**10**	**100%**



From the interviewed suppliers, 90% sells solar powered pumps. The remaining company was included in the survey because they will start selling solar pumps within the upcoming year. Overall, 60% of the companies provide both solar pumps and irrigation equipment.

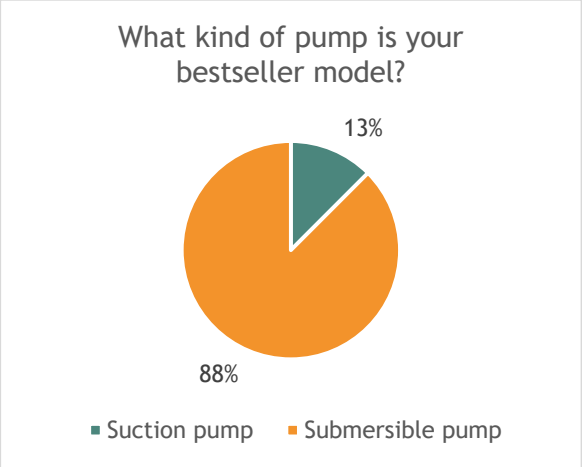
[6] Distribution Partners stock products, provide local support and training to local sales and service partners. Sales and Service Partners provide sales, installation and support to end customers.

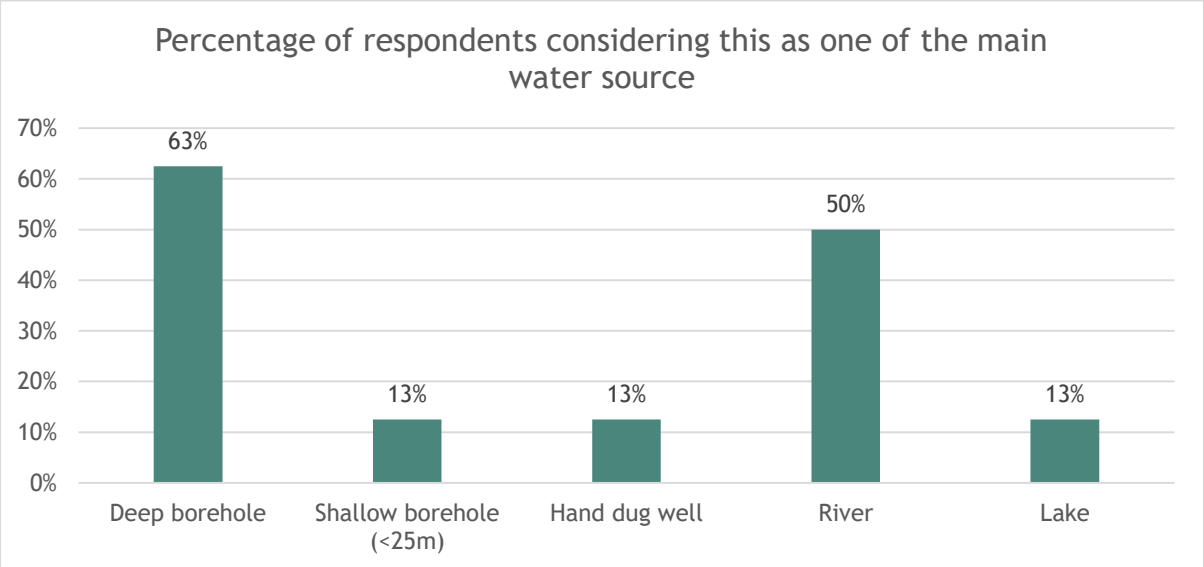


2.2 SPECIFICATIONS OF AVAILABLE TECHNOLOGIES

Pump types and water sources

Only one of the suppliers responded that its bestselling model is a suction pump. Suction pumps are most effective for surface water or groundwater up to maximum 7 meters' depth. The pump type is directly related to the water source, as is shown in the diagram below. The company selling suction pumps is the only one that considers shallow boreholes, hand-dug wells and lakes as one of the main water sources used. Interestingly, the majority of the solar pumps is currently used in deep boreholes (63%), followed by rivers (50%).





Pump models, capacity and prices

The following table shows the overview of the technical specifications and prices of the bestselling solar pump models in Mozambique. Most suppliers have more models available with different technical characteristics and prices. If a box is empty it means the number is unknown.

Table 4 Specifications of solar pumps available in Mozambique

Specifications of solar pumps in Mozambique							
Supplier in Mozambique	**Brand**	**Model**	**Price in Meticais**	**Total Watt-age**	**Rated flow (m3/h)**	**Head at rated flow (m)**	**Max head (m)**
Metaluz Lda	Taifu (Jiadi and Pumpman)	4SWN205-0.8N	32,760	1280	2.2	57	70
Sun Power Engineering	Solartech	SPM600H	20,000	270	10		190
Procampo Limitada	Cedar Solar	CEVA 100	870,000	9750	24	40	60
				5.5-12 kW			
Water Irrigation Solutions Moz, Lda	Futurepump	SF2	77,500	120	2	3-6	8
		SF1	50,778	80			
		SE1		60 or 120	1	3-6	
Blue Zone Mozambique Lda	Grundfos	SQF 2.5-2	140,000	1200	2,5	100	120
		Large range available, mainly SQF & CRF					SQF: 250
Soelec	Lorentz	PS2-100	80,000	327	2	40	50
Mudumene Trading	Lorentz	Hr700	390,000	800	5	120	140
		Hr200, Hr14, Hr7					
Solar Works	Futurepump	SE1		60 or 120	1	3-6	
		SF2		120	2	3-6	8
F&L Lda	Feili	FLD, FLA	210,000		60		100

Great care should be taken when comparing the prices of different pumps, since there are a lot of variables to take into account. It is recommended to determine the required daily yield (m3/day) and dynamic head (m) before making any inquiries about suitable pumps and prices. Practica is developing the Solar Irrigation Pump Selector mobile phone app to help technicians, farmers and sales agents to make this calculation and compare the feasibility of different pumps types for a given farm situation. There are also apps launched by particular brands for sizing, calculating and finding spare parts, such as the Grundfos GO solar app.

Another important aspect to take into account are the components that are included in the price. In fact, the number of components included showed the highest correlation with the

price (co-efficient of +0.74). This is a much stronger relation than the price and capacity (nominal flow) which only showed a correlation co-efficient of +0.27. The following table shows the components that are included in the different solar pump prices that were mentioned. It also shows that all solar pumps are provided with a warranty of on average 1.5 years. Generally, such warranties only apply to factory defects, and do not cover broken solar panels or damage from other accidents.

Table 5 Components included in solar pump prices

Components included in the indicated solar pump prices.
Empty boxes mean the component is not included in the indicated price.

Pump	Price in Meticais	Solar panels	Panel frame	Hose	Electrical cables	Installation	Transport	Warranty
Taifu	32,760				Yes			0.5 year
Solartech	20,000				Yes			3 years
Cedar Solar	870,000	Yes	Yes	Yes	Yes		Yes	1 year
Futurepump	77,500	Yes			Yes		Yes	1 year
Grundfos	140,000				Yes			1 year
Lorentz	80,000					Yes		1 year
Lorentz	390,000	Yes						3 years
Feili	210,000	Yes	Yes		Yes	Yes		unknown
	Percentage	**50%**	**25%**	**13%**	**75%**	**25%**	**25%**	**100%**

Irrigation equipment

The following figures show the characteristics of irrigation equipment provided by solar pump suppliers. The remaining respondents do not provide irrigation equipment with their pumps.

Table 6 (Solar) irrigation equipment available in Mozambique

(Solar) Irrigation equipment available in Mozambique

Supplier	Type	Brand	Surface unit	Price in meticais	Price in EUR[7]	Price per ha in EUR
SunPower Engineering	Drip	Shakti	Estimated at 500 m2	25,000	342	(6840)[8]
Procampo Limitada	Drip	Agriplas	1 ha	350,000	4795	4795

[7] A EUR/MZN rate of 1/73 was used in this report, following the official exchange rate on www1.oanda.com at 28/05/21.
[8] Since the surface unit was not indicated, the common unit size of 500 m2 per drip system was assumed here. In this report, any values between brackets have been estimated by extrapolation.

Water and Irrigation Solutions	Drip	Drip Tech India	500 m2	20,000	274	5479
F&L Lda	Drip	Netafim	500 m2	16,000	219	4384
Mudumene Trading	Spray tubes	San Fu	250 m2	20	0.27	11[9]

The table shows that the cost of a drip system does not vary more than 25% from the average once converted into costs per hectare. The average price of 4886 €/ha for a drip system is similar as the cost of drip systems in Benin (4444€/ha), and about 46% higher than the cost of a drip kit in Senegal (3346€/ha). The cost of spray tubes by Mudumene Trading in Chimoio is subsidized and therefore not representative. However, without subsidies the cost per hectare of spray tubes is still significantly lower than the cost of drip systems.

Like for the solar pumps, the components that are included in the provided unit prices for irrigation systems vary considerably.

Table 7 Components included in irrigation system prices

Components included in the indicated irrigation system prices							
Brand	**Tubes**	**Connections**	**Spare parts**	**Installation**	**Transport**	**Warranty**	**Estimated lifespan**
Shakti		Yes				3 years	10 years
Agriplas	Yes	Yes		Yes	Yes	1 year	>5 years
Drip Tech India	Yes	Yes	Yes			No	2 years
Netafim	Yes	Yes			Yes	1 year	2 years
San Fu				Yes		3 years	15 years
Percentage	**60%**	**80%**	**20%**	**40%**	**40%**	**80%**	

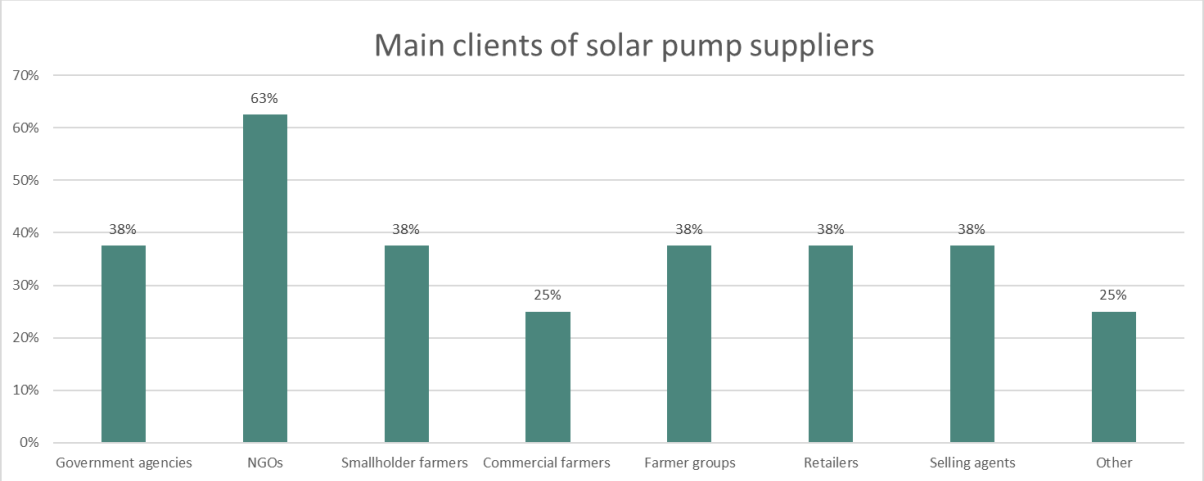
Except for Drip Tech India, all systems come with a 1 or 3 years' warranty. The suppliers offering a three years' warranty also indicate that the lifespan of their systems is very high: 10 to 15 years.

2.3 TARGET SEGMENT, DISTRIBUTION AND SERVICES

Main target segment

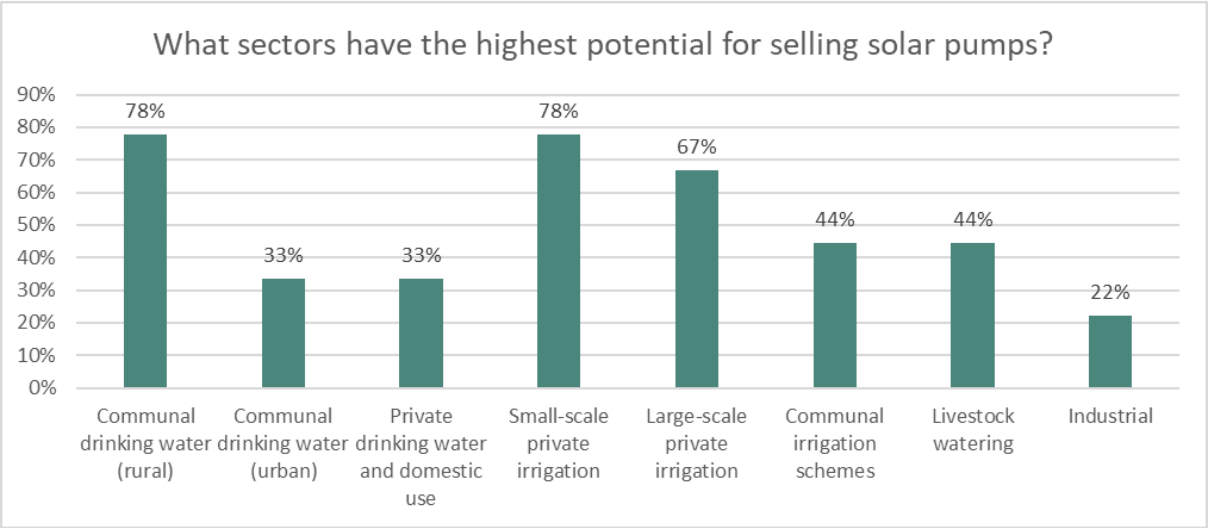
To the question "who is your main client" each respondent gave on average 3 answers.

[9] This price was subsidized by an NGO. The common cost for spray tubes is between 250 and 2100 EUR/ha depending on the supplier and materials used for installation.



NGOs are mentioned the most as the main client by pump distributors (63%). Almost all other client categories (government, smallholder farmers, farmer groups, retailers and selling agents) are mentioned as one of their main clients by 38% of the respondents. Commercial farmers are mentioned by only 25% of the suppliers.

Asked for the sectors with the highest potential for selling solar pumps, most suppliers (78%) indicated that small-scale private irrigation, as well as communal rural drinking water systems have the highest potential, closely followed by large-scale private irrigation (67%).



Four solar pumps available in Mozambique have an output that corresponds to the water requirement of smallholder farmers, i.e. those pumps providing 2 to 2.5 m3/hour, which allows for an irrigated area of 2000 to 4000 m2 depending on the location, season, crop, soil type and irrigation system. These are the Taifu, Futurepump SF2, Grundfos 2.5-2 and Lorentz PS2-100 models. The Solartech SPM600H has a larger flow but the lowest pump price, which also makes it a potential option for smallholder farmers. The Feili pump has a relatively high price, but includes almost all required components. The cost of the Taifu, Solartech, Lorentz and Grundfos pumps will increase considerably since the solar panels are currently not included in the price, see Table 5. It should be noted that there are important differences in capacity and quality of the pumps in the table below. It should be used as an indication of some available products and prices, and not as a tool for comparison.

Table 8 Overview of solar pumps for small-scale irrigation

	Overview of pumps applicable for small-scale irrigation						
Supplier in Mozambique	**Brand**	**Model**	**Price in Meticais**	**Price in EUR**	**Total Watt-age**	**Rated head (m)**	**Rated flow (m3/h)**
Metaluz Lda	Taifu (Jiadi and Pumpman)	4SWN2 05-0.8N	32,760	449	1280	57	2.2
Sun Power Engineering	Solartech	SPM600 H	20,000	274	270	?	10
Water Irrigation Solutions Moz, Lda	Futurepump	SF2	77,500	1062	120	3-6	2
		SE1	?		60 or 120	3-6	1
Blue Zone Mozambique Lda	Grundfos	SQF 2.5-2	140,000	1918	1200	100	2,5
Soelec	Lorentz	PS2-100	80,000	1096	327	40	2
F&L Lda	Feili	FLD, FLA	210,000	2877	?	?	60

Number of solar pumps sold

Overall the quantity sold by each distributor increases over time.

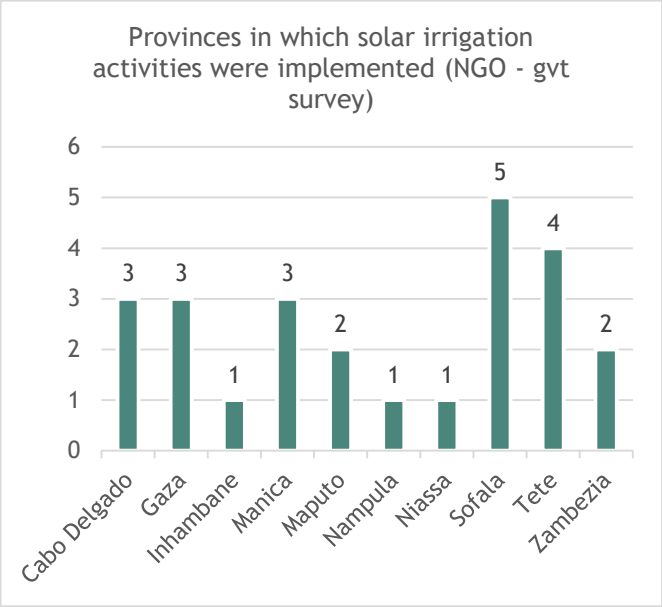
Table 9 Historic pump sales per company

Number of solar pumps sold per company in Mozambique				
	2020	**2019**	**2018**	**2017 and before**
Company A	30	20	15	0
Company B	450	420	435	320
Company C	10	15	9	5
Company D	100	100	100	0
Company E	200	180	150	(150)
Company F	2	3	0	0
Company G	25	6	2	1
Company H	3	0	0	0
TOTAL	**820**	**744**	**711**	**476**
Increase rate	**+10%**	**+5%**		

Local representation

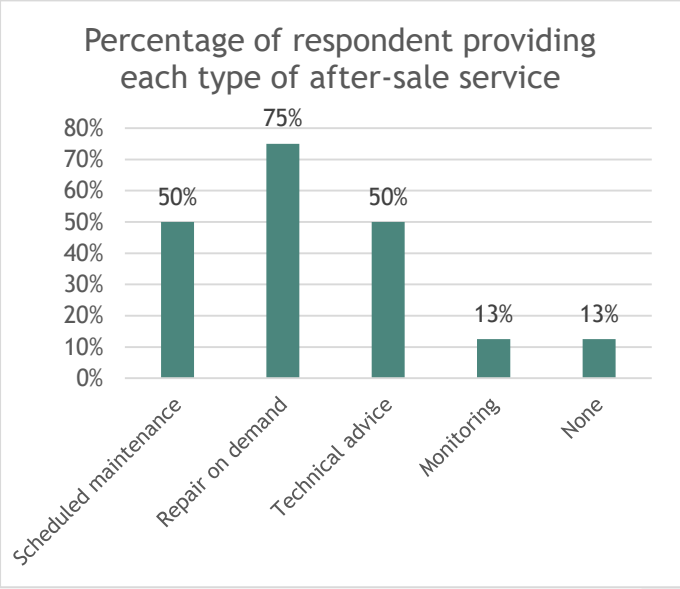
50% of the respondents have a representation in Maputo, the second location mentioned is Beira (37%). There is a clear relation between the towns with a local representation and the main provinces where the solar pumps are sold. However, there is no clear link between the location of local branches and the provinces where NGOs and government have distributed pumps.

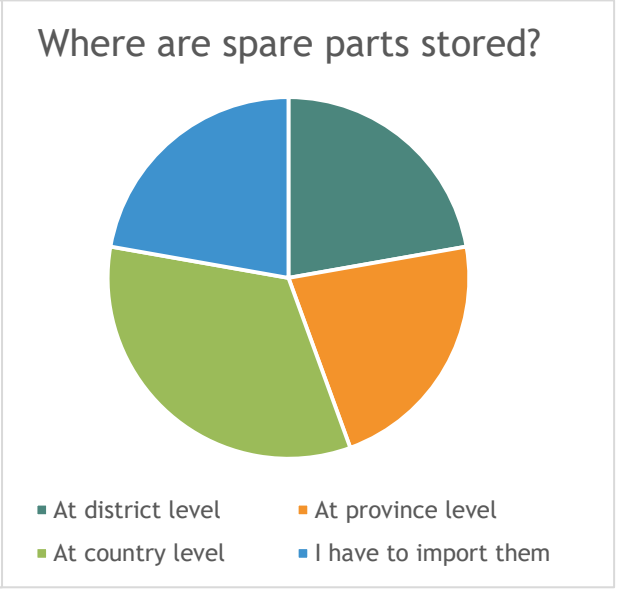
Main provinces where solar pumps are used (per supplier)	In which towns do you have a representation
Maputo	Maputo, Nampula and Beira
Nampula, Sofala, Gaza	Maputo
Gaza, Zambezia	Chokwe, Maxixe, Chimoio
Sofala, Cabo delgado, Zambezia, Tete	Matola and Beira
All over the country	Tete, Manica, Beira, Nampula
Inhambane	Maputo
Maputo	Maputo
Manica, Sofala	Chimoio



After sale services

Asked for the after-sales services offered, 75% of the suppliers provide repairs on demand. Half of the suppliers also provide scheduled maintenance services or technical advice to their clients. The companies have between 1 and 6 technicians available for after-services, yet the largest one (SunPower) stands out with 15 available technicians throughout the country. The availability of technicians seems to have a direct effect on the average downtime, or the time between a reported pump failure and reparation, which is 2 days according to SunPower, while the average downtime amongst all suppliers is 9 days. It should be noted that a downtime of 9 days could lead to a lost harvest in case the farmer cannot find an alternative pump in the meanwhile.





There is also a relation between the downtime and the level where spare parts are stored, with those suppliers storing spare parts at district level being able to fix failures in 2-3 days, while the two companies who need to import the spares both indicate a period of 15 days before a pump failure can be solved.

Finance solutions

Only two respondents indicated that they offer solar pumps with a credit or lease arrangement. One large distributor does so to known and trusted customers only, mainly because the interest rates at the banks are too high for their clients. The other supplier, a retailer, mentions that they provide credit only to clients with a monthly salary of more than 10,000 meticais. The money is subsequently collected through home visits and bank transfers. No company makes use of a central collection point, mobile money or other methods to collect instalments. The main reason for not providing finance solutions to their customers is that the companies do not have enough cash flow to pre finance the pumps (60%). One supplier mentioned the delayed payments by customers as a reason to not engage in credit provision.

The open question on what kind of support would be needed to offer (more) products on credit was answered in two ways. Half of the responses indicated that a bank facility with low credit rates should become accessible for farmers that are interested to buy a pump. The other half mentioned that a project or subsidy would be needed to make up for the deficit.

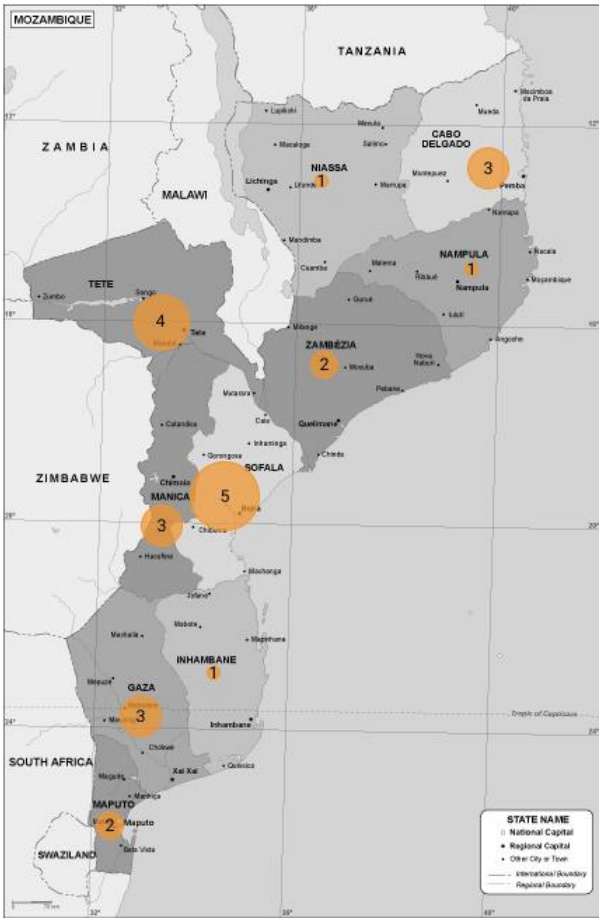
Success formula

Finally, each company was asked for their success formula in the solar pumps sector. As shown in the word cloud, three major types of strategies could be extracted from this, highlighting either the quality of the products, the importance of a country-wide network, and a close relationship with the clients.

3. SPIS SUPPORT INITIATIVES

3.1 OVERVIEW OF SPIS SUPPORT INITIATIVES

Supporting organisations like governments and NGOs have played a major role in upscaling solar-powered irrigation systems worldwide. This is not any different in Mozambique. In fact, the number of solar irrigation pumps distributed by the Mozambican government (4100 pumps) outweighs the sales of all private sector respondents combined (2751 pumps). This is possible since the pumps have been imported directly from the manufacturer, without involvement of the solar pump suppliers within Mozambique. Most NGOs involved in solar irrigation projects did purchase their solar pumps from local suppliers.



The map shows the number of solar irrigation projects hosted in each province. The reason that most solar pumps have been distributed in Central Mozambique seems to be the availability of recovery funds for the region that was hit by the Idai cyclone in 2019.

Unless mentioned differently, the data shown in this chapter result from the online survey sent to NGOs and government officials. Both government officials, as well as 7 out of 9 NGO respondents had effectively taken part in a solar irrigation project over the past years.

The following organizations have played a role in solar pump support initiatives (in random order). The respondents indicated that their roles included project management, coordination, implementation, promotion and technical assistance.

Table 10 Organizations with solar pump support initiatives

Organizations involved in solar pump projects in Mozambique (in random order and combination)	
Government institutes	**Donors / NGOs**
Instituto Nacional de Irrigação (INIR)	Oxfam, ADPP
Ministerio da Agricultura	Foundation for Community Development (FDC)
FUNAE, MIREME, FNDS, MINAG, MOPH	GEF
Provincial Directorate of Agriculture and Fisheries-DPAP	World Bank
Agencia do Vale de Zambeze (2x)	Netherlands Embassy (2x)
UniLúrio, IQQEM	Spanish development embassy
District Services for Economic Activities (SDAE) (2x)	JICA,
Agrarian Development Fund-FDA,	IFAD
Provincial directorate of agriculture and IIAM	Sida
DNA, AIAS, ADEMC, CMCM	Adel Sofala

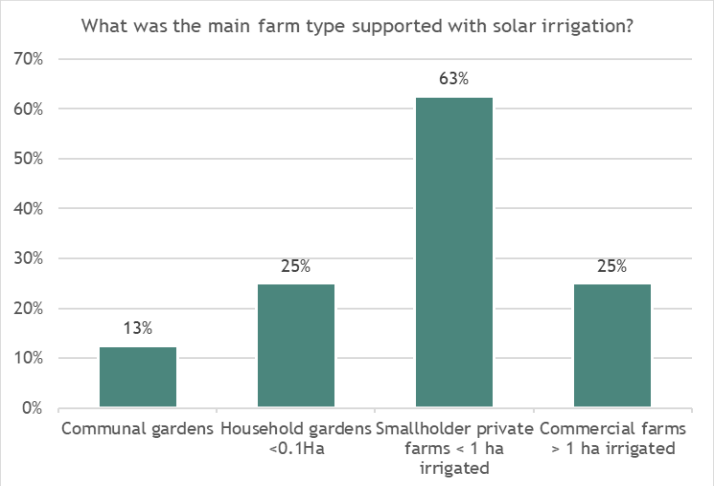
FDC (FASER window)	GIZ (EnDev and GBE)
Direcção Provincial de Agricultura e Segurança Alimentar (DPASA)	UNIDO FAO, Care, World Vision

3.2 TARGET AND DISTRIBUTION

As mentioned above, the largest solar irrigation initiative in Mozambique is implemented by the government institute INIR in 10 provinces. For its first SPIS initiative, funded by the World Bank, INIR distributed 4200 solar pumps and drip kits of 500 m2 amongst farmers in 10 provinces between 2018 and 2019. The technology was made available through the provincial (DPASA) and local government institutes. The target were arid and semi-arid districts. At the moment INIR is purchasing another 2400 kits of the same equipment for Idai affected farmers in Inhambane, Sofala, Tete and Manica provinces. INIR mentions that the willingness of the private sector (equipment suppliers) to invest is one of the main challenges related to solar irrigation in Mozambique.

The World Bank, through its Mozambique Energy for All (ProEnergia) project (2019-2023) has committed further investments in off-grid energy including solar water pumps for agriculture, through the project's sub-component B2: Off-grid results-based financing (RBF) Facility managed by FUNAE. This sub-component will target selected provinces in the northern region, where the poverty incidence is high [10]. The FASER window implemented by GIZ Endev and GBE and the FDC provides financial incentives to the private sector with the aim to accelerate the sustainable growth of renewable energies including solar irrigation pumps[11].

The specific farm segment targeted by the different supporting organizations are mainly smallholder private farms with less than 1 ha irrigated. Since the large INIR projects target both household gardens (<0.1ha) and smallholder private farms (<1ha), this group will receive the largest number of solar pumps by far.



As for the target groups, most organizations tend to focus on farmers that are currently irrigating by hand (50%). Yet in absolute numbers, most pumps will be distributed amongst individual rain-fed farmers, as

10 https://documents1.worldbank.org/curated/fr/594061554084119829/pdf/Mozambique-Energy-for-All-ProEnergia-Project.pdf

11 https://www.faser.co.mz/landing/Structure

this is the target group indicated by INIR. The project by UNIDO and ADPP has almost as many beneficiaries (4000) yet this is because their target consist of communal farmers with on average 50 farmers per solar pump[12]. See the picture of the ADPP communal solar irrigation system[13].

3.3 APPROACH TO SUSTAINABILITY

Most respondents (57%) indicated that training farmers on operation and maintenance is their main approach towards sustainability. Another 29% mentioned that shared ownership and income generated from common fields can be used to assure maintenance and sustainability.

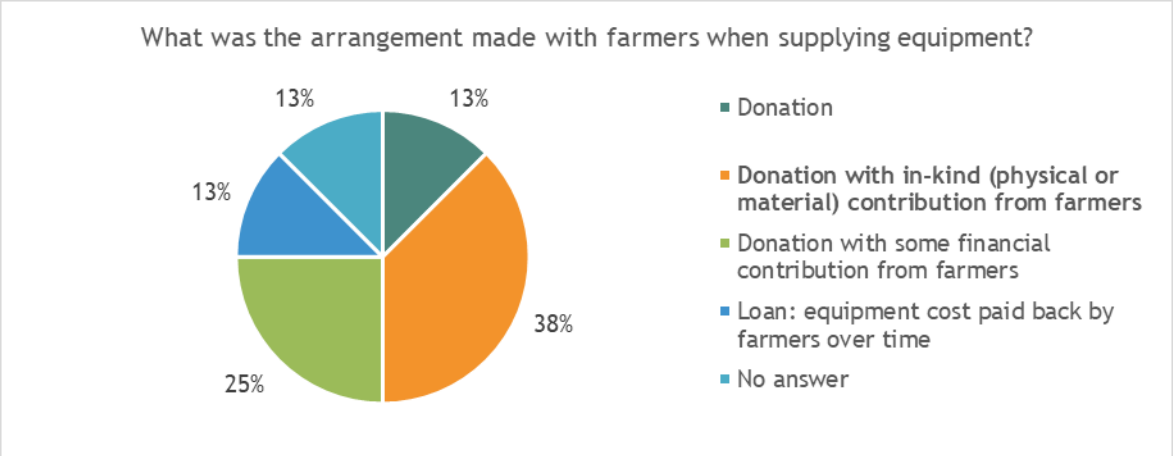
The following overview compares the costs of some solar irrigation systems installed through government or NGO projects. All costs include solar panels, irrigation technology and installation. When assuming 2000 m2 per farmer, following the characteristics of small solar pumps as shown in chapter 2, the price of a package for one individual farmer would range from 1350 to 3580 Euro. Two respondents have done a cost benefit analysis, showing a return of investment in 2 and 3 years respectively.

Table 11 Cost of solar irrigation projects in Mozambique

Project	**Number of beneficiaries**	**What is the total number of solar pumps distributed in the project?**	**What was the total cost of the solar pumps and irrigation systems?**	**What was the estimated total area (ha) covered by solar irrigation in the project?**	**Estimated Cost EUR/ha[14]**
A4Labs	3	5	3375 (EUR)	0.5 ha	6,750
Susainable Energy for All	4000	80	406000 (MZN)	47 ha	9,466
INIR	4200	4100	USD 4 million	210 ha	15,613
APSAN-Vale	15	15	OVER 2000 USD	> 3ha	8,197
PROSUL	2 associations		5,229,921 MZN	4 ha	17,910

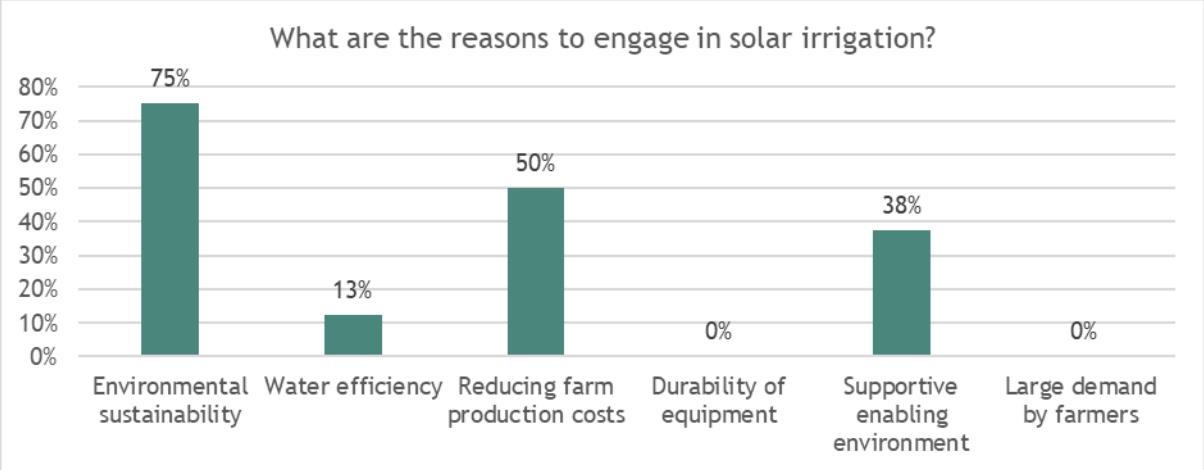
In terms of the arrangement with farmers, the survey results indicated that just over 50% of the projects has donated the pumps without a financial contribution from the farmers. The INIR project includes "some financial contribution from farmers".

[12] https://www.unido.org/stories/smallholder-farmers-mozambique-embrace-solar-energy
[13] https://m.facebook.com/adppmoz/posts/1631304883668239/
[14] A EUR/USD rate of 1/1.22 was used in this report, following the official exchange rate on www1.oanda.com at 28/05/21. The values are estimated since some currencies and units had to be interpreted by the author, through cross-checking with the replies on other questions.



3.4 STRATEGIES FOR FUTURE INIATIATIVES

Overall, 67% of the organizations considers the introduction of solar irrigation as a success. The remaining projects were either still running or called a failure due to the theft of solar panels (in 2 projects). Yet, 7 out of 8 organizations mention that they plan to continue promoting solar irrigation activities in the near future. The remaining one does not, due to a change of thematic focus. As shown below, the main reason for organizations to engage in solar irrigation is the environmental sustainability (75%), followed by reducing farm production costs (50%). Desk research also found reduction of CO2 emissions and reducing farm costs as the major rational by NGOs to promote SPIS in Mozambique[15].

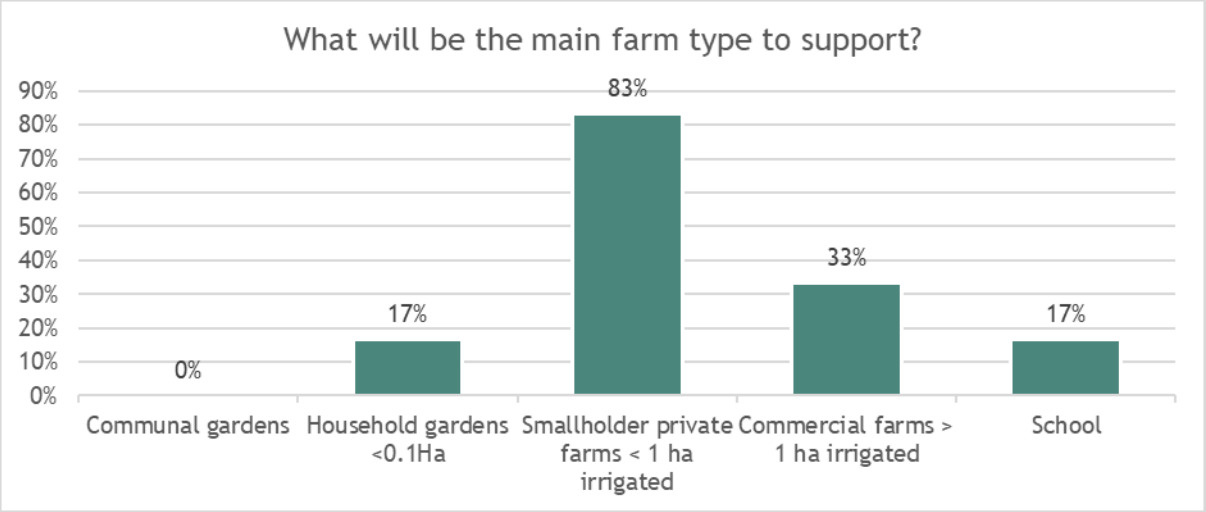


The main farm type to support in future projects will be smallholder private farms.

15 https://reliefweb.int/sites/reliefweb.int/files/resources/CSA_Profile_Mozambique.pdf

https://www.tse4allm.org.mz/index.php/en/midia/pequenos-agricultores-em-mocambique-adotam-a-energia-solar

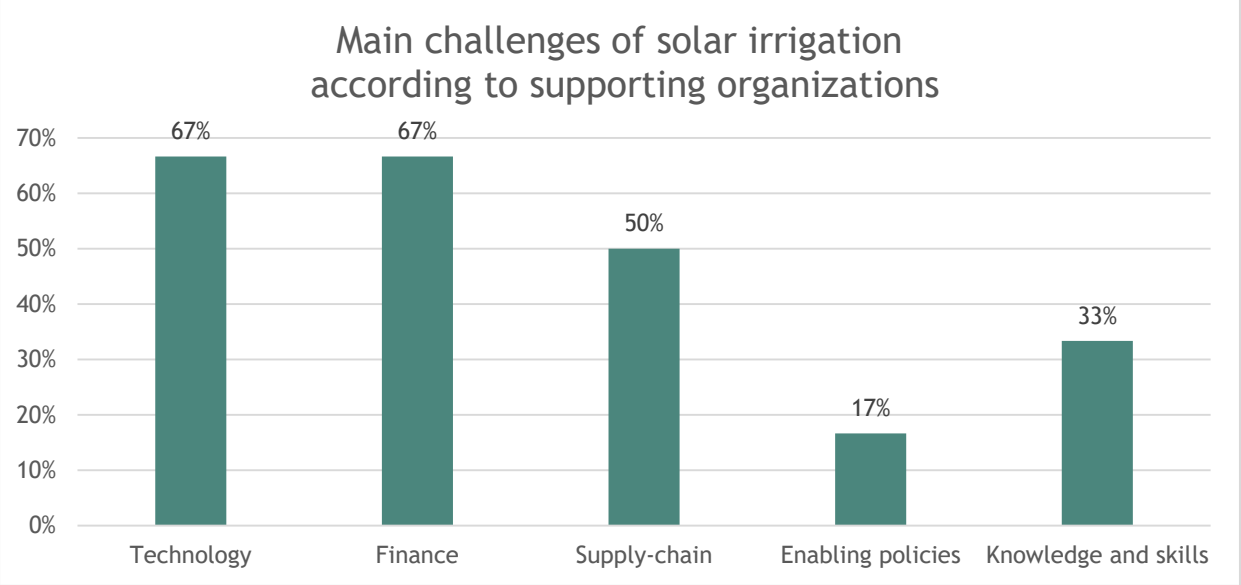
https://www.ace-taf.org/wp-content/uploads/2021/04/Stand-Alone-Solar-SAS-Market-Update-Mozambique.pdf



Furthermore, most organizations (67%) will demand a financial contribution from farmers in future projects. A donation without financial or in-kind contribution is no longer an option for any of the respondents.

4. BARRIERS FOR UPSCALING

The organizations that have worked on solar irrigation projects in Mozambique indicate that the main challenges are related to the technology, supply chain (commercial) and financing of solar pumps. This chapter is based on the survey responses as well as in-depth interviews with two key experts from the Mozambican private sector to elaborate and reflect on the different barriers.



4.1 TECHNICAL BARRIERS

The technical implications of using solar pumps instead of fuel powered pumps are ample. Respondents of the organization survey indicate correctly that the pumps have a smaller capacity, some types are less mobile or cannot function in every type of water source, panels can be stolen, repairs can be challenging and conventional irrigation technologies are not always compatible.

To start with the water source, chapter 2.2 has shown that the majority of the solar pumps is used in deep boreholes and rivers. Due to the very high cost of deep boreholes, and the limited number of farmers who have access to land along perennial river streams, the scope of solar irrigation is severely reduced if not more water sources can be used. One respondent of the supplier survey therefore suggests to improve the availability of hydrological data. This could help to identify the zones where water is most accessible. A provincial government official indicated that it is the technology that should be adapted, in order to allow for a much larger pumping head and discharge. A key supplier stressed that technically there is no limit to solar irrigation, and mentioned examples in Malawi where one solar pump provides 1000 m3 of water per day, and a solar irrigation system in Chimoio province with a planned yield of 500 m3/day. Unfortunately, there is a direct relation between the capacity and output of a solar pump, the required energy and the cost of the system. This implies that systems with a larger capacity exist, but at a higher cost.

The lack of optimal irrigation technologies for solar systems is another important aspect. Irrigation by furrows or flooding is very time consuming and leads to high water losses, which compromises the available water volume for the plants and thereby the size of the irrigated field. Since the capacity of solar pumps is smaller and less flexible compared to fuel-powered pumps, there is a need to optimize the application system. Optimal application systems for solar pump are featured by a high water efficiency and low pressure, as both aspects directly impact on the water volume available for the crops, for a given solar pump. Optimal irrigation technologies for solar pumps include spray tubes, drip systems, rainmakers, large diameter hosepipes and basins with spray cans. Only drip systems are widely available in Mozambique, yet its cost is prohibitive for most small-scale farmers.

The surveys as well as various reports[16] indicate that the risk of theft is an important constraint related to solar powered pumps in Mozambique. The issue of stolen panels links to mobility of the pump and panels. Most solar submersible pumps are featured by a relatively large number of panels that are fixed on a panel mount and therefore prone to theft. The available suction pumps come with the benefit that panels can be taken home.

Another observation from the surveys is that repairs of SPIS are challenging. This results from a number of factors. First of all, solar pumps are relatively new and therefore there is limited knowledge and experience amongst farmer communities and technicians. Secondly, the technology is often installed by the supplier and, depending on the brand, submersible solar pumps are either difficult to access or even impossible to repair locally. Thirdly, spare parts are not widely available and need to be requested from the supplier. Most of this is a supply chain problem, resulting from the limited market development of solar irrigation in Mozambique. Another issue is that not all users receive training. The private sector survey indicated that only 40% of the suppliers provide training to the users (see chapter 2.1). For one of the largest SPIS projects the question on how the maintenance is arranged was answered by N/A.

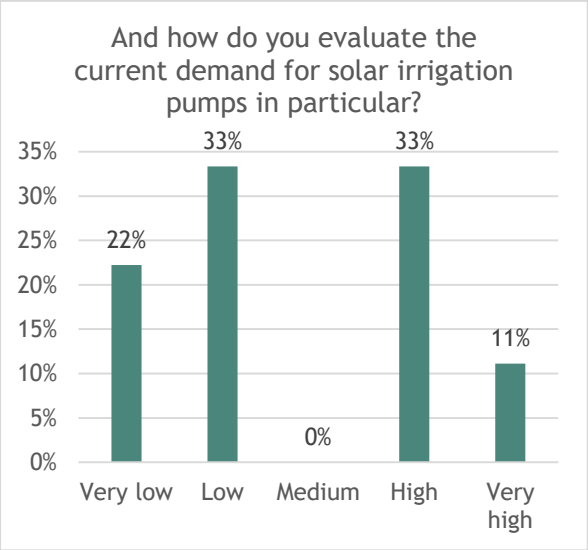
[16] https://amer.org.mz/wp-content/uploads/2019/04/aler_mz-report_oct2017_web.pdf

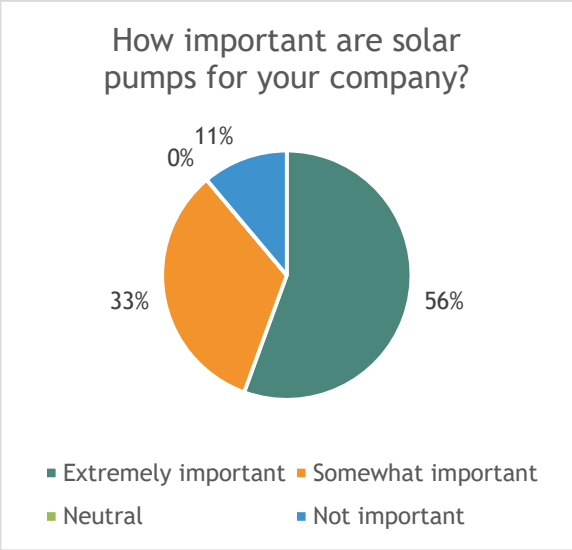
https://www.government.nl/documents/reports/2016/10/18/end-term-review-of-the-intervention-renewable-energy-for-rural-development

One key expert stressed that training is the key to success and sustainability. Especially large projects in which a lot of pumps are installed without investing in training usually lead to failure within a very short time.

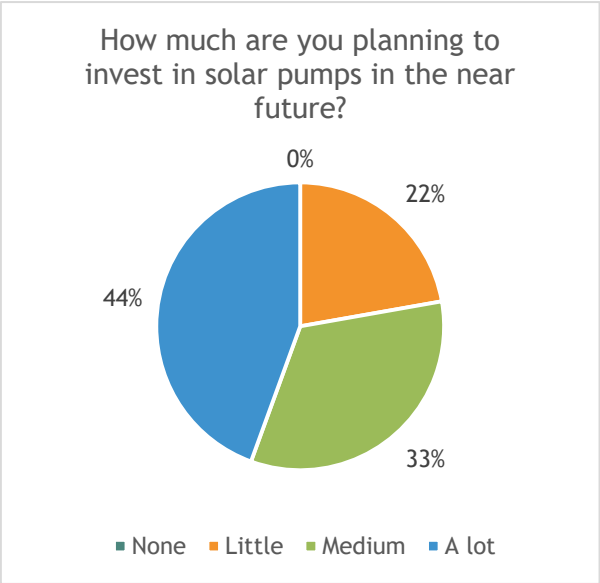
4.2 COMMERCIAL BARRIERS

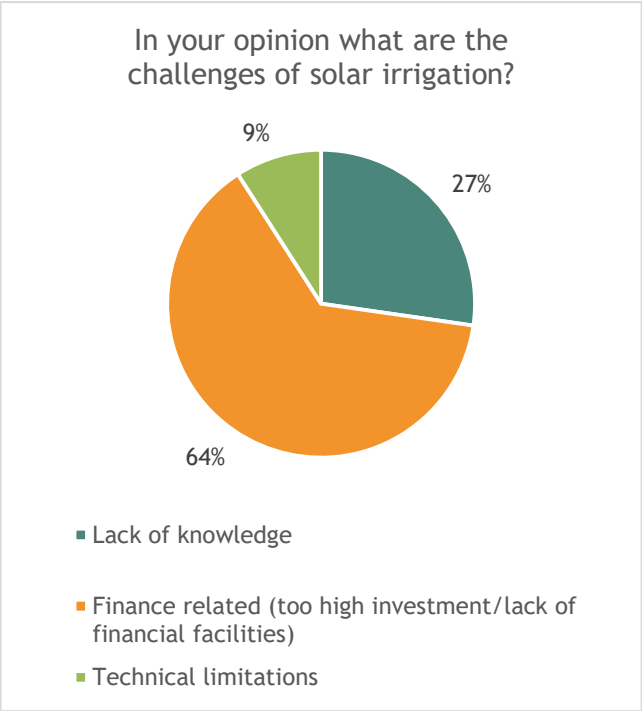
The absence of local supply chains, including services and spares, was mentioned as the third most important challenge by governments and NGOs. The government even noticed a limited willingness to invest in solar irrigation amongst the local private sector. As shown in the graph below, the private sector itself is divided on the status of the current demand for solar irrigation pumps. Yet, 56% considers solar pumps as extremely important for their company.





Another 44% of the suppliers is planning to invest a lot in solar pumps in the near future and only 22% plans to invest little. Hence, the interest and willingsness to invest in solar pumps expressed by the private sector is positive. The challenges they face however are mainly finance-related (64%) or resulting from a lack of knowledge (27%).





Unlike in some other countries, the private sector does not face major problems to import pumps. The procedures are manageble and with the new pre-warning system in the port of Maputo the customs and importation time has been reduced to only 2-3 days. Foreign currency and loans to order pumps from abroad can be obtained through the commercial banks in Mozambique without any major issues.

Tax exemptions

The suppliers all indicate that there is no tax exemption on solar pumps. However, sometimes there are exceptions made to import pumps for particular projects. Generally, suppliers need to pay 17% VAT and 7.5% import tax on solar products[17]. The import tax applies to the CIF cost, hence including the value of the cost, insurance and freight of the pumps. As a comparison, hand pumps are VAT exempt and agricultural technologies are featured by an import tax of only 5%. However, solar irrigation pumps do not classify as such. Apart from the import tax, there are a lot of other charges during the importation process, linked to the obligatory services of the port companies assuring the logistics, operation, storage, clearance and administration. The total importation costs add up to 30-40% of the CIF cost, according to the key experts interviewed. As a result, the solar pump business in Mozambique is less competitive than in Zimbabwe, where solar products are free from import duties, or than South Africa.

The suppliers recommend the government to:

- Issue duty exemptions or reduction on import taxes (incl. on solar panels) (4/8)
- Provide financial resources to small communities to buy the equipment (1/8)
- Increase knowledge on solar/renewable energies (2/8)
- Create a legislation for selling solar pumps (1/8)

[17] This information provides by key experts corresponds to the findings by https://gggi.org/site/assets/uploads/2019/02/20190218_-Country-Brief_Mozambique.pdf

General recommendations by the private sector to scale solar irrigation in Mozambique includes a focus on:

- Information and training (44%)
- Investment (22%)
- Access to finance for farmers (22%)
- Reducing importation costs (11%)

4.3 FINANCIAL BARRIERS

The following two responses to the organizational survey explain why the main financial barrier related to solar powered irrigation systems is its high cost:

"The capital cost for the transition to solar is high for most rural farmers. They need financial instruments to support them. On the other hand the country needs more technology vendors strategically located to be able to supply and support rural communities across the country."

"Many farmers and organizations don't have access to technology to use solar irrigation and to purchase it is very expensive for the majority of farmers and small organizations."

As shown in chapter 3.3, a price of 1000 EUR is not uncommon for a smallholder farmer solar irrigation system. It goes without saying that the vast majority of farmers in Mozambique cannot make such a high investment upfront. Yet, access to credit is a big problem in Mozambique. The interest charged by commercial banks is 19.3% and the eligibility criteria by banks and micro finance institutes do allow smallholder farmers to take a loan. A specific problem in Mozambique is the fact that land is owned by the state, which means that it cannot be used as collateral when applying for a loan.

Brainstorming about credit facilities for farmers, the interviewed key experts from the private sector indicated that bank loans are preferable, since it is not their expertise to manage loans, sign contracts with farmers or assess the credit risk of different applicants. It is preferred that a donor signs a contract with a bank to provide low interest loans to farmers. The bank should then pay the supplier. There are examples of such projects in which loans with only 5% interest have been made available to farmers.

The new BCI Super package that was launched in April 2021 in order to stimulate the use of renewable energy for productive use, is an example of a credit facility that specifically highlights solar-powered irrigation as one the activities to finance. This credit line is funded through a guarantee of 1 million USD provided by UNIDO, managed by FUNAE and implemented by the BCI bank[18]. The provided loans can be a maximum of 50,000 USD, to be paid back within 1-3 years, with a 7.5% interest rate. The clients need to bring in 25% of the investment as upfront payment. The target groups are companies, NGOs, cooperatives and associations, that need to have a BCI bank account, show salary slips for 2 months, provide a viable technical and financial business plan and submit the request online. As a result, this arrangement is not likely to be accessible by smallholder farmers.

As shown in chapter 3, the alternative: to donate solar pumps to farmers is no one's favourite option either, as the lack of ownership or genuine interest generally comprises the effective use and maintenance of a technology. Another recommendation is to provide subsidies to end users. One of the key experts therefore recommends to partly subsidize pumps and let farmers pay about 20% of the remaining cost. The other key expert

[18] https://www.tse4allm.org.mz/index.php/en/midia/a-unido-em-parceria-com-o-bci-financia-sistemas-de-energia-renovavel-para-usos-produtivos-na-zona-rural-de-mocambique

mentioned the SolTrain project as an example of a partial subsidy approach. This arrangement has been established to promote and sell solar heating systems. The process is as follows:

1) Interested clients need to comply with a set of minimum requirements and submit a number of forms.
2) The submitted forms need to be approved by the Mozambican Technology Institute and by the donor. This takes on average two weeks.
3) After approval the client pays 50% of the total sum, after which installation begins.
4) The donor pays the remaining 50% to the company. There is no loan or interest involved.

According to the solar pump supplier this model is easy to copy and applicable to farmers, even though there are a lot of forms involved. He suggested that criteria could include: 3 clients in the same area, owning at least 1 hectare of land, and having their farm registered with an association or as a company. He also advices to adopt a flexible project plan and adjust the criteria if it does not work.

Though these ideas may stimulate the solar irrigation market, it is not very inclusive for small-scale farmers. A very different approach, which is not available yet in Mozambique, are Pay-As-You-Go (PAYGO) arrangements that are provided by a technology supplier without involvement of banks of micro finance institutes. This approach has grown mainly in the solar home sector and is now starting to be applied by some solar pump suppliers in a number of African countries. The advantage of PAYGO approaches is the reduction of paperwork and a much more accessible financial product that is linked to the cost and benefits of a solar irrigation system. The largest provider of solar irrigation pumps through PAYGO is the Kenyan company Sunculture, which has recently raised 25 million USD to expand their sales to Senegal, Togo and Ivory Coast. Their pumps are linked with mobile payment devices, offered by partner companies such as BBOXX. The Sunculture company as well as similar finance solutions for solar pumps are not available in Mozambique yet.

It should be noted that despite the general optimism regarding solar home kit suppliers providing PAYGO solutions, a stakeholder consultation meeting with Mozambican companies involved in solar productive use systems did point out some key challenges[19]. The main issues are related to payment collection (lack of mobile network), the duration of payback time (customers need over a year to pay back solar home systems), difficulties to assess credit profiles of customers, fiscal issues (high VAT and import taxes), the risk of market distortion by grant providing programmes (due to a lack of coordination) and the lack of start-up or incubation funding windows (since small early-stage companies are not eligible for most grants and other incentive mechanisms).

5. RECOMMENDATIONS AND OPPORTUNITIES

To increase access to solar powered irrigation for the target group of GBE, i.e. small-scale farmers in Mozambique, solutions should provide an answer to the three main barriers, i.e. the technical, commercial and financial aspects. The key to sustainable scaling is to increase access to integrated SPIS solutions by making solar irrigation support initiatives more inclusive.

19 https://beyondthegrid.africa/wp-content/uploads/MOZ-BGFA-Mozambique-Stakeholder-Workshop-Report.pdf

An experienced key expert recommended that a sustainable support initiative for solar irrigation should start with a selection of feasible areas, followed by the identification of key partners, farmers and associations that have experience with irrigation. Next to this, training local technicians should be part of any solar pump installation to solve minor problems when necessary. A third recommendation by the respondents, which is in line with observations from the World Bank[20], is the need to coordinate efforts to promote solar irrigation, in order to avoid market distortion or counterproductive initiatives and learn from each other.

To increase the technical scope for solar pumps, it is recommended to increase access to water. This is because the main sources currently used for solar irrigation: perennial rivers and deep boreholes, are not accessible for most farmers. Low-cost technologies to drill or dig wells could be promoted, as well as technology that allows submersible pumps to be used in ordinary open wells (e.g. the so-called pump jacket recently launched by Lorentz together with the PS2-100 pumps).

To increase sustainability, it is necessary to invest in the development of supply chains and local technicians. Chapter 2.3 has shown that the availability of technicians and spare parts at district level is directly linked to a company's ability to assure rapid repairs. The risk of harvest failure due to pump downtime could severely impact farmers' capacity to pay back a loan, so available maintenance services are even more critical when providing pumps on a credit basis. Training of technicians, advisors and users is indicated as the key to success and sustainability. Key experts from the private sector said that even though solar irrigation can be scaled easier with commercial farms with means to invest, solar irrigation is also a sustainable option for donor-funded community projects. This is because solar-powered systems tend to have both a longer technical lifespan and a longer lasting social durability than fossil fuel powered systems as no running costs are involved.

In order to reduce the financial gap for farmers to start solar irrigation, a dual strategy including both subsidies and inclusive credit mechanisms is recommended. Subsidies could be justified by the fact that benefits on the environment are in the interest of the global community. Subsidies can be provided by the government, as has been done in India and is now also planned by various governments in West Africa.

Alternatively, donors can engage with the financial sector or provide direct support to suppliers, respectively providing them with guarantees or the necessary start capital to offer pumps on a credit base. Chapter 2.3 showed that the main reason for solar pump suppliers to not currently provide finance solutions to their customers is the lack of cash flow to pre finance the pumps (60%). Providing start-up capital and implementation support for PAYGO solutions is recommended in particular because of the low administrative requirements and the direct link that is established between the farmer and the supplier, sharing a mutual interest in a well performing solar pump and irrigation system.

Finally, the involvement of subsidies and other donor support mechanisms related to solar irrigation provides a way to combine multiple purposes, such as promoting renewable energy and increasing opportunities for youth or women. Female farmers in Mozambique have less access to finance, markets and technical innovations including irrigation

[20] https://documents1.worldbank.org/curated/fr/594061554084119829/pdf/Mozambique-Energy-for-All-ProEnergia-Project.pdf

systems[21]. Targeting vulnerable groups increases the base, justification and resources for financial support mechanisms. The opportunity of targeting female farmers was very well understood by Sunculture, who named their 5000 solar pump partnership in West Africa : "Women and Solar Entrepreneurship"[22]. Hence, when private sector and donor priorities find common ground, the development of inclusive supply chains can accelerate considerably.

[21] http://www.mgcas.gov.mz/st/FileControl/Site/Doc/4021perfil_de_genero_de_mocambique.pdf

[22] https://www.edf.fr/groupe-edf/espaces-dedies/journalistes/tous-les-communiques-de-presse/edf-accelere-sur-le-marche-off-grid-en-afrique-en-misant-sur-une-nouvelle-offre-et-les-competences-locales

ANNEXES

ANNEX A: CONTACTS PRIVATE SECTOR

Contacts of suppliers of solar pumps and/or irrigation solutions in Mozambique.

Organisation	Products	Contact person	Position	Contact
Afridev Mati	Vergnet solar pumps	Dario Amade		dario.amade@afridevmati.co.mz
Aquáfrica LDA, Nampula	Solar pumps			aquafricalda@gmail.com
Blue Zone Moçambique Lda	Grundfos solar pumps	Leif Hansen	Director	comercial@bluezone.co.mz
F&L LDA, Maputo	Sun king power and Feili solar pumps, drip irrigation	Desmund Matengu		desmondmatengu@gmail.com
Fenix/Epsilon	PAYGO systems. Solar pumps to be piloted	Anton Arkhipov		antark@epsilonenergia.co.mz
G.M. Todd Irrigation cc.	Lorentz solar pumps	Carlos		carlos@gmtoddirrigation.co.za
Macquip Moz Beira	Solar pumps			admin@macquipmoz.com
Metaluz	Jiadi and Pumpman (both Taifu) solar pumps	Ashif Raza Munshi	Regional Manager	metaluz@metaluz.net
Next Electricidade e iluminação	Daywatt24 solar pumps			next@next-mz.com
ProCampo	Cedar solar pumps, drip irrigation	João Carlos Frade	Director	frade@tvcabo.co.mz
Mudumene Trading Chimoio	Lorentz solar pumps, Spray tubes	Claudia		savon@teledata.mz
Soelec	Lorentz solar pumps	Nelson Amaral	Gestor de operações	soelec@soelec.co.mz
SolarWorks	PAYGO systems. Futurepump solar pumps	Evelien Rietdijk	Manager Irrigation Technologies	e.rietdijk@solar-works.nl
SunPower	SolarTech and Shakit solar pumps	Alberto Pondeca	Managing Director	alberto.pondeca@sunpowermz.com
Tecap / Casa do Agricultor	Irrigation systems	Romao Chemane		info@tecap.co.mz / romao.chemane@tecap.co.mz
Water Irrigation Solutions Moz, Lda	Futurepump and Jain solar pumps, drip irrigation	Muhammad Alibhai	Sales manager	muhammadalibhai.wis@gmail.com